



## **The 4 January, 2009, landslide at "Los Chorros" village, San Cristóbal Verapaz, Guatemala: context and a preliminary assessment**

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On 4 January, 2009, more than 5 million cubic metres of limestone and calcareous breccias detached from the "Los Chorros" hill and travelled along a tributary ravine of the Chixoy river in the municipality of San Cristóbal Verapaz, department of Alta Verapaz, Guatemala. At the time of this landslide, several persons were crossing roads and foot trails downstream of the release area. As of 14 January, authorities had reported 38 casualties, 50 missing and 5 injured persons. Along the landslide path, a 1.2 km segment of the 7W National Highway was destroyed, cutting the sole access route between San Cristóbal Verapaz and the western department of Quiché where numerous inhabitants of Alta Verapaz commute to work, especially during the coffee harvest season from October to March (with its peak on January). In response to this disaster, the Guatemalan government established four priorities: search and rescue activities, relief aid to victims and their families, evacuation of villages at risk and selection and construction of a temporary access route and a permanent road. In an attempt to provide additional elements to decision-makers of the Guatemalan authorities, this report is aimed to characterise the context of this landslide from a geosciences perspective. Preliminary assessments of the 4 January event and of other potentially unstable zones identified in the surrounding areas are also performed.

The first accounts of ground instabilities in this area date back to 1590 when a 4.0 MS earthquake was associated with the collapse of a karst cave. In 1881, a Guatemalan newspaper reported that the San Cristóbal (Chichoj) lagoon was created after a ground subsidence was triggered by an earthquake. In 1983, after less than one year of operations, a ~50 m segment of the 26-km long pressure tunnel in the Chixoy hydro electrical project was damaged due to an anhydrite karst produced during tunnel operations. In response to this event, repair and strengthening works were carried out and power plant operation was re-started in 1985. At the end of November 2008, small landslides occurred in the surroundings of the area of the 4 January event and on mid December, a few number of larger slides occurred killing 2 persons and blocking the 7W National Highway. Rumbling noise was often reported by passersby. No heavy rainfall seems to be associated with the triggering of these events and rainfall accumulations during November 2008 (transition from rainy to dry season) were below the monthly normal rainfall. Immediately prior to these landslides, there are no earthquake events located in this area by the Guatemalan seismic network. During November 2008, three cold fronts affected Guatemala, producing freezing temperatures in some locations especially during the third week of November. In the surroundings of the area of the 4 January landslide, frost susceptibility ranges from low to medium. The landslide took place in a catchment that follows a NNE fault which to the south intersects the EW Chixoy-Polochic fault (part of the transcurrent boundary of the North American and the Caribbean plates) 5 km downstream of the release area. Some fumarolic activity is currently observed in the landslide site. Based on the above elements and on observations from field reconnaissance missions, some hypotheses are formulated to explain the conditioning and triggering factors for the events in November and December and particularly for the 4 January landslide. These hypotheses are aimed to help to identify other potential instabilities in the surroundings.

Back-calculation of flow parameters for the 4 January landslide has been possible based on estimation of velocities using video footage of the event and simulations with two different models for landslide dynamics across three-dimensional terrain: DAN3D developed at the University of British Columbia and RAMMS developed at the WSL Institute for Snow and Avalanche Research SLF. These back-calculated parameters have enabled the estimation of impact areas due to landslides that can be potentially released in surrounding slopes with similar instability features to the “Los Chorros” hill. Even though these estimations may be improved as more information becomes available for this event, the authors hope that this report contributes with some elements for decision-makers regarding short- and intermediate-term activities in response to this disaster.